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NEUTRINO EXPERIMENTS IN THE 25-FOOT BUBBLE CHAMBER

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ABSTRACT

We list neutrino experiments that we considered using the 25-foot bubble chamber. This chamber is a powerful and, for many experiments, a unique tool for neutrino studies when used as a double chamber. We strongly recommend that the chamber be built without delay and, if possible, even made deeper than presently planned. We further recommend that development of the double-chamber technique be continued vigorously.

We have considered neutrino experiments with emphasis on the capabilities of the 25-foot chamber. As indicated in detail below, we find the 25-foot chamber an extremely powerful and unique tool with which to study neutrino interactions at high energies.

In order to peg our calculations to some numbers, we have made the following assumptions:

1. 2×10^{13} proton/pulse on the target.

2. The neutrino spectrum given by Nezrick and Kang in Fig. 24, SS-146. This spectrum agrees with calculations by Wachsmuth SS-129. F. Nezrick has calculated a preliminary anti-neutrino spectrum for us. This is given in SS-142.

3. 1.8 meter beam radius.

4. One million pulse unit exposure.

5. The following standard bubble-chamber setups:

a. 25-foot chamber filled with hydrogen, deuterium, or neon (21-foot fiducial track length assumed, i.e., 72 m^3).

b. 25-foot chamber with a diaphragm after 14 feet, the front part being filled with hydrogen or deuterium (10-foot fiducial track length or 31 m^3) and the back part with 50% Ne-50% hydrogen (atomic percent) or pure neon (8-foot fiducial track length or 25 m^3).

Tables I and II give the numbers of events expected for 10^6 pulses as a function of neutrino energy if the cross section were 10^{-38} cm^2/nucleon and only one kind of nucleon (n or p but not both) could participate.

Although we have indicated above a double-chamber design with a diaphragm as standard, this does not imply that this is the most useful shape for neutrino interactions. A cylindrical shape going about 15 feet into the chamber would have the great advantage of having sidewise gamma ray and neutron detection capabilities at the cost of a loss in event rate. The optimum size is a matter for careful simulation studies.

The experiments considered fell into the following groups depending on chamber and beam:

1. Double chamber and normal beam

   Inelastic cross section (Bjorken type analysis)

   W search

   Adler test

   Antineutrino hyperon production and selection rule tests

   Vector meson (ρ, H, CTC) production

2. Hydrogen/Deuterium and low-energy beam

   Elastic cross section, N^* production, hyperon production

3. Neon filling with Pb plate, and high-energy beam

   Lepton pair production

The new feature over the previous reports is the overwhelming reliance on neon and on double-chamber techniques for the bulk of the experiments. It is clear from the above list and the individual reports given later that the 25-foot chamber operated in a double-chamber mode is a very useful instrument. Because of this mode of operation the 25-foot size of the chamber is badly needed. We strongly recommend that this chamber be built and not be scaled down; if the optical tests on the 7-foot model prove successful, we suggest that a modification to give even greater width and depth be considered.

We recommend that development of the double-chamber technique be continued vigorously for the 25-foot chamber and that neon be ordered to be available for the chamber at turn-on time. We certainly would like a full deuterium filling; but if it proves impossible for budgetary reasons, we would prefer half of a deuterium filling (which could be used in an internal target) and neon to having no neon at all.

We also note that according to the reports of Peoples,[1] Sard,[2] Huson,[3] and Jovanovic,[4] background cosmic-ray muon problems appear severe. We recommend that the chamber and installation be designed so that shielding will be placed above it in its initial location.

The neutrino experiments considered fall into the following groups:

I. Experiments feasible in bubble chambers and unique to that technique or very competitive with counter techniques:

- Total cross section
- Inelastic cross section (Bjorken-type analysis)
- W search
- Adler test
- Test of selection rules ($\Delta S/\Delta Q$, $\Delta t = 1/2$ etc.)
- Vector meson production

II. Experiments involving policy decision:

- Elastic cross sections
- N^* production
- Hyperon production form factors

Question: To determine the elastic form factors in detail and the various form factors for N and hyperons up to q^2 of about 10 $(\mathrm{BeV}/c)^2$, it is best to use low energy neutrinos; should this be done at NAL or BNL? If NAL runs at low energy, it will have greater intensity than BNL and will have a larger bubble chamber. Furthermore, if NAL runs at 30 BeV on an alternate pulse basis, this cycle will take only about 1 second and slow down the cycle time for high energy pulses by only about 20%. However, the experiment probably can be done at BNL. Is it wise for NAL to concentrate on experiments which can be done at BNL or should it concentrate on its unique range of energies?

If local V-A theory is correct, then an exposure to the standard NAL neutrino beam gives little form factor information from elastic events not obtained by an exposure to a low energy beam. The small (1%) fraction of events with $q^2 > 10$ $(\mathrm{BeV/c})^2$ are expected to be dominated by g_M which is already determined by electron scattering (if CVC is correct). Such a pessimistic view assumes, however, that there can be no surprises. Some non-local theories (although not the W) could be observed in such a high energy exposure and the search for them is clearly important. Furthermore, this could check for an anomalous axial vector form factor or second-class currents.

The problems involving the N^* and hyperon production at high energies are quite similar to the elastic scattering and the same considerations apply there.

III. Experiments very difficult for the bubble chamber (and also very difficult by counter techniques):

Lepton pair production

Neutrino electron scattering

Neutrino proton scattering ($\nu p \rightarrow \nu p$)

Papers by the individual members of this subgroup describe the experiment considered above in more detail.

REFERENCES

[1] J. Peoples, Background in the 25-Foot Chamber When Used for Neutrino Physics, National Accelerator Laboratory 1968 Summer Study Report B. 1-68-97, Vol. I, p. 197.

[2] R. D. Sard, Cosmic-Ray Backgrounds in Neutrino Experiments, National Accelerator Laboratory 1969 Summer Study Report SS-15, Vol. II.

[3] R. Huson, J. Kopp, and V. Vandenberg, Camera View of Cosmic Rays in the 25-Foot Bubble Chamber, National Accelerator Laboratory 1969 Summer Study Report SS-83, Vol. II.

[4] D. D. Jovanovic, Muon Background in the 25-Foot Chamber, National Accelerator Laboratory 1969 Summer Study Report SS-81, Vol. II.

Table I. Events/10^6 Pictures if $\sigma = 10^{-38}$ cm^2/Nucleon (Assuming Only One Kind of Nucleon Can Take Part), if 2×10^{13} p/pulse, 1.8 m Beam Radius, ν Flux From Fig. 24, SS-146.

ν Momentum BeV/c	Flux/m^2/10^6 Inc. protons	10-foot H or D Events	21-foot H or D Events	8-foot 50% neon 50% hyd.	8-foot neon	21-foot neon
5-10	1000	2.2×10^4	4.6×10^4	8.8×10^4	1.76×10^5	4.6×10^5
10-15	650	1.4	2.9	5.6	1.1×10^5	2.9
15-20	210	0.46	0.97	1.8	3.6×10^4	0.97
20-25	65	1.44×10^3	3.0×10^3	5.7×10^3	1.14	3.0×10^4
25-30	25	0.55	1.16	2.2	4.4×10^3	1.16
30-35	13.5	3.0×10^2	6.3×10^2	1.2	2.4	6.3×10^3
35-40	8	1.8	3.8	7.2×10^2	1.4	3.8
40-50	10	2.2	4.6	8.8	17.6×10^2	4.6
50-60	5.5	1.22	2.6	4.8	9.6	2.6
60-70	3.0	6.6×10^1	14.0×10^1	2.6	5.2	14.0×10^2
70-80	1.40	3.0	6.4	12.0×10^1	2.4	6.4
80-90	0.5	1.1	2.4	4.4	8.8×10^1	2.4
90-100	0.16	0.36×10^1	0.76×10^1	1.44×10^1	2.8×10^1	0.76×10^2
		43,700	Total			

[a]Hydrogen interactions ignored

Table II. Events/10^6 Pictures for $\bar{\nu}$ Using Same Assumptions As ν Calculation, But Using Nezrick $\bar{\nu}$ Curves of SS-142.

$\bar{\nu}$ Momentum BeV/c	Flux/m^2/10^6 Inc. protons	10-foot H or D Events	21-foot H or D Events	8-foot 50% neon 50% hyd.	8-foot neon	21-foot neon
5-10	360	7.9×10^3	1.65×10^4	3.2×10^4	6.35×10^4	1.65×10^5
10-15	285	6.2	1.3	2.45	4.8	1.28
15-20	75	1.6	3.45×10^3	0.63	1.2	0.34
20-25	23	5.1×10^2	1.0	2.0×10^3	3.9×10^3	1.0×10^4
25-30	10	2.2	4.7×10^2	0.85	1.8	4.7×10^3
30-35	4.2	0.92	1.96	3.7×10^2	0.75	1.96
35-40	1.9	4.2×10^1	0.89	1.7	3.3×10^2	0.89
40-50	2.1	4.6	0.95	1.85	3.7	0.95
50-60	1.0	2.25	4.8×10^1	0.9	1.8	4.8×10^2
60-70	0.63	1.35	2.8	0.5	1.05	2.8
70-80	0.31	0.65	1.4	2.6×10^1	0.5	1.4
80-90	0.1	2.2×10^0	4.5×10^0	0.9×10^1	1.7×10^1	4.5×10^1

[a]Hydrogen interactions ignored